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CLINICAL RESEARCH
Prevention and epidemiology

Suicide loss, changes in medical care utilization, and hospitalization for cardiovascular disease and diabetes mellitus

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Aims The impact of suicide loss on family members' cardiometabolic health has little been evaluated in middle-aged and elderly people. We investigated the effect of suicide loss on risks for cardiovascular disease (CVD) and diabetes mellitus (DM) in suicide completers' family members using a national representative comparison group.

Methods and results The study subjects were 4253 family members of suicide completers and 9467 non-bereaved family members of individuals who were age and gender matched with the suicide completers in the Republic of Korea. National health insurance data were used to identify medical care utilization during the year before and after a suicide loss. A recurrent-events survival analysis was performed to estimate the hazard ratios (HRs) of hospitalizations for CVD, DM, or psychiatric disorders, after adjusting for age, residence, and socioeconomic status. Among subjects without a past history of CVD, DM, or psychiatric disorders, the increased risks of recurrent hospitalizations were observed for CVD [HR 1.343, 95% confidence interval (CI) 1.001–1.800 in men; HR 1.240, 95% CI 1.025–1.500 in women] and DM (HR 2.238, 95% CI 1.379–3.362 in men; HR 1.786, 95% CI 1.263–2.527 in women). In subjects with a past history of CVD, DM, or psychiatric disorders, the number of medical care visits decreased after a suicide loss, and suicide completers' family members showed lower rates of hospitalization for CVD and DM than the comparison group.

Conclusion Compared with non-bereaved family members, suicide completers' family members without a past history of CVD, DM, or psychiatric disorder showed a high risk of hospitalization for those conditions.

Keywords Suicide loss • Hospitalization • Cardiovascular disease • Diabetes mellitus

Introduction

The World Health Organization (WHO) estimates that approximately one million people die by suicide each year.[1] There are approximately half a million suicides in Asia, resulting in ~12 million family members experiencing loss and grief.[2] In the Republic of Korea, the number of family members of suicide completers has been estimated at 0.1 million (or six per suicide) in 2010.[3,4] Suicide is a major public health challenge because, in addition to the loss of the deceased, it has adverse effects on family members. Compared with typical bereaved or non-bereaved individuals, family members of suicide completers are more likely to suffer from mental illnesses such as depression,[5,6] anxiety,[7] suicide ideation,[5] and suicidal behaviour.[8,9]

Although research has focused on the mental health of children and adolescents,[6–8] little is known about the resulting physical illnesses in middle-aged and elderly family members of suicide completers. Some studies have shown that bereaved people have a

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greater number of medical care visits after a loss than the non-bereaved,[10,11] whereas others have reported no differences.[12,13] The sample size, study period, and cause of the loss could be related to this discrepancy. However, the number of medical care visits is likely affected by having a past history of chronic illnesses, which has not been considered in the literature.

Previous studies have suggested that psychological stress resulting from family-member loss increases risk of cardiovascular disease (CVD)[14,15] and diabetes mellitus (DM).[16] Suicide loss might also cause severe psychological stress among family members, and the adverse effects of that stress might be stronger than those experienced by individuals in typical bereavement (i.e. not a result of suicide) due to social isolation and stigma.[17] Severe psychological stress may cause deterioration in physical health, especially in the middle-aged and elderly. Consequently, there might be an increase in the incidence of CVD and DM. However, to the best of our knowledge, the risks for developing CVD and DM in suicide completers' family members have not been investigated. In the current study, we investigated changes in medical care utilization after suicide loss and the effect of suicide loss on the risk for acute hospitalization for CVD and DM among the family members of suicide completers, using a nationally representative comparison group.

Methods

Study subjects

We used a three-stage process to select subjects: (i) identification of suicide completers, (ii) selection of individuals who were age and gender matched with suicide completers, and (iii) identification of family members of both suicide completers and matched individuals (*Figure 1*). Suicide cases from 2002 ($n = 8631$) and 2003 ($n = 10\,932$) were identified from death statistics of the National Statistical Office. The Republic of Korea has adopted a national health insurance system based on a family, consisting of a subscriber and financially dependent family members (i.e. the subscriber's lineal ancestor, spouse, lineal descendant, or sibling). Thus, family members of each suicide completer could be identified through data from the Health Insurance Review and Services Agency (HIRA). After excluding individuals with no family identification information and with family members who had committed suicide together ($n = 10$), 4582 (1997 in 2002 and 2585 in 2003) suicides were selected; the average age and the proportion of men were similar to those of all suicide completers in 2002–2003.

To compare physical and mental illnesses in the family members of suicide completers with that in the general population, we randomly selected two individuals who were age and gender matched with each suicide ($n = 9164$) from among Korean health insurance subscribers and their dependents in the relevant year. After excluding one-person (i.e. suicide completer or matched individual) families, 3611 families of suicide completers and 7815 matched families were selected. The family members of each subject were identified using data from HIRA, and 9155 subjects among family members of suicide completers and 22 250 subjects among non-bereaved family members were selected. We restricted the analysis to individuals who were ≥ 40 years of age because hospitalization for CVD and DM in those <40 years is rare. Thus, 4253 family members of suicide completers and 9467 non-bereaved family members were included in the final analysis (see Supplementary material online, *Table S1*). This study was approved by the Institutional Review Board of Yonsei University Health System (approval number 4-2011-0273), Seoul, Republic of Korea.

Medical care utilization

Medical care visit data of all Koreans, which includes age, gender, health insurance premiums, family identification number, and diagnosis code according to the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10), are typically reviewed by the HIRA. Inpatient and outpatient medical care visits for CVD [ischaemic heart disease (ICD-10 code: I20-I25), stroke (I60-I69), hypertensive disease (I10-I15)], DM (E10-E14), and psychiatric disorders (F00-F99) during the year before and after a suicide loss were identified. Medical care visits in the non-bereaved group were based on the date of each matched suicide. A past history was defined as any medical care visit for CVD, DM, or psychiatric disorders during a 1-year period before a suicide loss. Deaths among the study population were identified from death statistics of the National Statistical Office.

Statistical analysis

We divided the study population according to potential factors affecting medical care utilization a priori, as follows: gender and past history of CVD, DM, or psychiatric disorders. Because CVD, DM, and psychiatric disorders are chronic illnesses requiring regular follow-up, past history of medical care visits for CVD, DM, or psychiatric disorders was thought to change the baseline likelihood of hospitalization for those conditions. In addition, the likelihood of medical care utilization varies across gender in the Republic of Korea.[18] Thus, all analyses were performed separately, according to whether a subject had a past history of CVD, DM, or psychiatric disorders, and by gender.

Determination of socioeconomic status was based on health insurance premium, which is based on family income and immovable property; socioeconomic status was then categorized into quartiles. Beneficiaries of the Medical Aid Programme were assigned to quartile 1. Area of residence was classified as metropolitan, urban, or rural.

In the survival analysis, hospital admissions for CVD, DM, and psychiatric disorders during the year after a suicide loss were considered. A Cox proportional hazard model was used to estimate the hazard ratios (HRs) and the 95% confidence intervals (CIs), after adjusting for age, residence, and socioeconomic status. Because hospitalization for each subject was a multiple and ordered event (see Supplementary material online, *Tables S2 and S3*), a recurrent-events survival analysis was performed with a Prentice–Williams–Peterson (PWP) total time model,[19] which is one of the stratified Cox proportional hazard models; the first event was also analysed using a Cox proportional hazards model. Because we used a family-based sampling method and there may be a contextual effect of family, the identification number of each family was included as a random effect in all the Cox proportional hazards models.

All analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC, USA) and using randomly generated identification numbers to mask the identities of the subjects. During the analysis, we checked for violations of the assumptions of the proportional hazard models, by incorporating interaction terms between each variable and time; none were significant for all variables.

Results

The characteristics of the suicide completers' family members and the comparison group are presented in *Table 1*. Among subjects without a past history of CVD, DM, or psychiatric disorders, suicide completers' family members consisted of 1586 men and 2373 women, and the comparison group consisted of 2677 men and 4285 women.

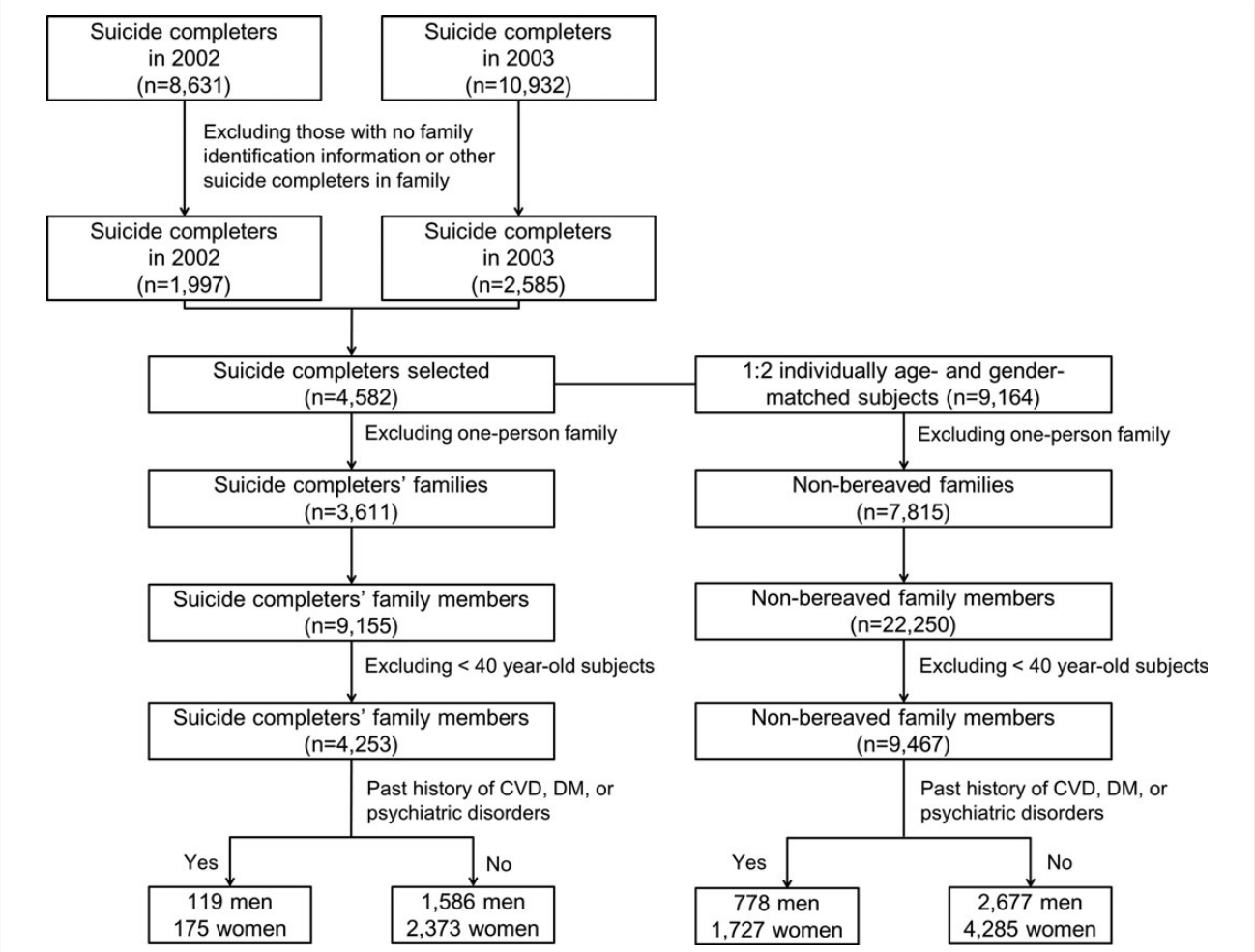

Figure 1 Flow chart of study subjects selection. CVD, cardiovascular disease; DM, diabetes mellitus.

An increase in the number of total medical care visits after suicide loss was observed in individuals without a past history of CVD, DM, or psychiatric disorders, while a decrease among those with a past history (*Table 2*). In non-bereaved family members, the median (interquartile) values of the number of medical care visits in those without a past history of CVD, DM, or psychiatric disorders were 6.0 (8.0−12.0) in men and 8.0 (3.0−15.0) in women (data not shown), which were higher than those of suicide completers' family members.

The proportion of patients hospitalized for CVD, DM, or psychiatric disorders was higher in suicide completers' family members compared with non-bereaved family members in those without a past history of those illnesses (see Supplementary material online, *Table S2*).

In the recurrent-events survival analysis, among subjects without past history of CVD, DM, or psychiatric disorders, suicide completers' family members were at an increased risk of hospitalization for CVD within the year following a suicide loss, when compared with non-bereaved individuals (HRs 1.34 and 1.24; 95% CI 1.00−1.80 and 1.03−1.50 for men and women, respectively) (*Table 3*). A decreased risk was observed among those with a past history of CVD, DM, or psychiatric disorders (HRs 0.54 and 0.53; 95% CI 0.38−0.76 and 0.41−0.68 for men and women, respectively). Among those without a past history of CVD, DM, or psychiatric disorders, the HRs of hospitalization for DM and psychiatric disorders increased significantly after a suicide loss for both genders. Among those with a past history, only the risk of hospitalization for DM decreased significantly.

We checked the interactive effects of past history of CVD, DM, or psychiatric disorders on the association between suicide loss and hospitalization for those illnesses. All interaction terms were statistically significant, with the exception of psychiatric hospitalization in women ($P < 0.001$ for CVD and DM hospitalization in both genders; $P = 0.024$ and $P = 0.248$ for psychiatric admission in men and women, respectively).

Discussion

Summary

In the present study, among those without a past history of CVD, DM, or psychiatric disorders, we found that (i) although the number of medical care visits increased after suicide loss, suicide completers'

Table 1 Baseline characteristics of suicide completers' family members and non-bereaved family members, separated by a past history of cardiovascular disease, diabetes mellitus, or psychiatric disorders

	Without a past history of CVD, DM, or psychiatric disorders			With a past history of CVD, DM, or psychiatric disorders		
	Suicide completers' family members	Non-bereaved family members	*P*-value[a]	Suicide completers' family members	Non-bereaved family members	*P*-value[a]
Men, *n* (%)	1586	2677		119	778	
Age (years)						
40–49	582 (36.7)	1050 (39.2)	0.255	18 (15.1)	169 (21.7)	0.237
50–64	591 (37.3)	964 (36.0)		53 (44.5)	332 (42.7)	
≥65	413 (26.0)	663 (24.8)		48 (40.3)	277 (35.6)	
Area of residence						
Metropolitan	1402 (88.4)	1317 (49.2)	<0.001	101 (84.9)	388 (49.9)	<0.001
Urban	158 (10.0)	1047 (39.1)		14 (11.8)	287 (36.9)	
Rural	26 (1.6)	313 (11.7)		4 (3.4)	103 (13.2)	
Socioeconomic status[b]						
Quartile 1	72 (4.5)	125 (4.7)	0.516	10 (8.4)	42 (5.4)	0.424
Quartile 2	763 (48.1)	1348 (50.4)		54 (45.4)	352 (45.2)	
Quartile 3	261 (16.5)	420 (15.7)		22 (18.5)	127 (16.3)	
Quartile 4	490 (30.9)	784 (29.3)		33 (27.7)	257 (33.0)	
Women, *n* (%)	2373	4285		175	1727	
Age (years)						
40–49	737 (31.1)	1741 (40.6)	<0.001	24 (13.7)	262 (15.2)	0.235
50–64	958 (40.4)	1524 (35.6)		63 (36.0)	712 (41.2)	
≥65	678 (28.6)	1020 (23.8)		88 (50.3)	753 (43.6)	
Area of residence						
Metropolitan	2147 (90.5)	2153 (50.3)	<0.001	156 (89.1)	843 (48.8)	<0.001
Urban	195 (8.2)	1638 (38.2)		16 (9.1)	653 (37.8)	
Rural	31 (1.3)	494 (11.5)		3 (1.7)	231 (13.4)	
Socioeconomic status[b]						
Quartile 1	121 (5.1)	199 (4.6)	0.129	10 (5.7)	137 (7.9)	0.368
Quartile 2	1189 (50.1)	2265 (52.9)		96 (54.9)	833 (48.2)	
Quartile 3	464 (19.6)	828 (19.3)		27 (15.4)	300 (17.4)	
Quartile 4	599 (25.2)	993 (23.2)		42 (24.0)	457 (26.5)	

CVD, cardiovascular disease; DM, diabetes mellitus.
[a]The difference between suicide completers' family members and the comparison group. A χ^2 test was used.
[b]Quartile 1 is the lowest; all quartiles are based on the health insurance premium rate grade.

family members sought medical care less frequently than did non-bereaved family members; and (ii) suicide loss significantly increased the risk of acute hospitalization for these disorders. In addition, among those with a past history of CVD, DM, or psychiatric disorders, the number of medical care visits decreased after suicide loss, and both the number of medical care visits and the risk of hospitalization were lower compared with the non-bereaved. Several previous studies have reported that bereaved family members seek medical care more frequently than do the non-bereaved,[10,11] which is opposite of the results of our study. Although we cannot fully explain this discrepancy due to observational nature of our study, the possible explanation is the effect of stigma on family members' medical care utilization via social isolation,[17] which might be unique to Asians.

Cardiovascular disease

Compared with non-bereaved family members, the risk of hospitalization for CVD among suicide completers' family members without a past history of CVD, DM, or psychiatric disorder was increased by 34 and 24% in men and women, respectively, after a suicide loss. Suicide loss causes severe psychological stress, which might result in the development and exacerbation of CVD through elevation of catecholamine and cortisol levels,[20,21] as well as through changes

Table 2 Changes in the number of medical care visits among suicide completers' family members, separated by a past history of cardiovascular disease, diabetes mellitus, or psychiatric disorders[a]

	Without a past history of CVD, DM, or psychiatric disorders		With a past history of CVD, DM, or psychiatric disorders	
	Before suicide loss	After suicide loss	Before suicide loss	After suicide loss
Men, *n* (%)				
Total	1.0 (0.0–2.0)	2.0 (0.0–6.0)	6.0 (4.0–12.0)	3.0 (0.0–9.0)
Age (years)				
40–49	1.0 (0.0–2.0)	1.0 (0.0–4.0)	5.0 (3.0–8.0)	1.0 (0.0–7.0)
50–64	1.0 (0.0–1.0)	2.0 (0.0–7.0)	6.0 (3.0–10.0)	3.0 (0.0–8.0)
≥65	1.0 (0.0–2.0)	4.0 (0.0–9.0)	9.0 (4.5–19.5)	3.0 (0.0–11.5)
Area of residence				
Metropolitan	1.0 (0.0–2.0)	2.0 (0.0–6.0)	6.0 (3.0–11.0)	3.0 (0.0–8.0)
Urban	1.0 (0.0–1.0)	2.0 (0.0–6.0)	7.5 (4.0–18.0)	3.5 (0.0–13.0)
Rural	1.0 (0.0–3.0)	2.0 (1.0–8.0)	6.0 (5.0–16.0)	2.0 (0.0–5.0)
Socioeconomic status[b]				
Quartile 1	1.0 (0.0–1.0)	2.0 (0.0–6.0)	8.0 (4.0–20.0)	3.0 (1.0–5.0)
Quartile 2	1.0 (0.0–2.0)	2.0 (0.0–6.0)	6.0 (3.0–10.0)	3.5 (0.0–10.0)
Quartile 3	1.0 (0.0–1.0)	2.0 (0.0–7.0)	6.5 (2.0–15.0)	1.0 (0.0–7.0)
Quartile 4	1.0 (0.0–1.0)	2.0 (0.0–6.0)	7.0 (5.0–15.0)	2.0 (0.0–9.0)
Women, *n* (%)				
Total	1.0 (0.0–2.0)	3.0 (0.0–9.0)	6.0 (3.0–10.0)	5.0 (0.0–11.0)
Age (years)				
40–49	1.0 (0.0–2.0)	3.0 (0.0–7.0)	5.0 (2.0–6.0)	6.5 (1.5–10.5)
50–64	1.0 (0.0–2.0)	4.0 (0.0–10.0)	6.0 (3.0–8.0)	6.0 (1.0–13.0)
≥65	1.0 (0.0–2.0)	4.0 (0.0–9.0)	7.0 (3.0–13.0)	4.0 (0.0–10.0)
Area of residence				
Metropolitan	1.0 (0.0–2.0)	3.0 (0.0–9.0)	6.0 (3.0–10.5)	5.5 (0.0–10.5)
Urban	1.0 (0.0–2.0)	3.0 (0.0–8.0)	6.0 (3.0–8.0)[c]	4.0 (0.0–13.0)[c]
Rural	0.0 (0.0–2.0)	5.0 (1.0–11.0)		
Socioeconomic status[b]				
Quartile 1	1.0 (0.0–1.0)	4.0 (0.0–11.0)	5.5 (2.0–10.0)	2.0 (0.0–6.0)
Quartile 2	1.0 (0.0–2.0)	3.0 (0.0–9.0)	6.0 (3.0–9.5)	6.0 (1.0–10.5)
Quartile 3	1.0 (0.0–2.0)	3.0 (0.0–9.0)	8.0 (4.0–17.0)	4.0 (0.0–15.0)
Quartile 4	1.0 (0.0–2.0)	4.0 (0.0–8.0)	6.0 (3.0–11.0)	5.0 (0.0–13.0)

CVD, cardiovascular disease; DM, diabetes mellitus.
[a]The number of inpatient or outpatient medical care visits was expressed as a median (25–75%).
[b]Quartile 1 is the lowest and is based on the health insurance premium rate grade.
[c]For women, urban ($n = 16$) and rural areas ($n = 3$) of residence were combined due to low sample sizes.

in haemodynamics related to cardiovascular risk factors.[22] In addition, behavioural changes after bereavement, such as alcohol consumption, could contribute to the increased risks of CVD.[6,23] Previous research has suggested an increased risk for myocardial infarction within 1 day of the death of a significant other for patients with a past history of myocardial infarction.[14] In our study, among those with a past history of CVD, DM, or psychiatric disorders, suicide completers' family members showed a decrease in the number of medical care visits after a suicide loss and were at lower risk of hospitalization for CVD during the subsequent year compared with the non-bereaved. This implies that suicide completers' family members with underlying CVD had fewer opportunities to detect or treat disease exacerbation, which might be linked to an increased risk of cardiovascular death in the long term. Many studies have shown that the bereaved are at the highest risk for death during the 6 months after a family loss, but the risk remains high for several years.[24] We could not observe any significance for mortality due to the small sample size (12 deaths), so additional research that includes a larger sample size and a longer term follow-up period is necessary.

Table 3 Hazard ratios[a] (95% confidence intervals) for hospitalizations for cardiovascular disease, diabetes mellitus, and psychiatric disorders after suicide loss, separated by a past history of any of these conditions

	First event[b]		Recurrent events[c]	
	Men	Women	Men	Women
Without a past history of CVD, DM, or psychiatric disorders				
CVD	0.967 (0.675–1.387)	1.202 (0.944–1.531)	1.343 (1.001–1.800)	1.240 (1.025–1.500)
Hypertensive disease	1.226 (0.803–1.873)	1.382 (1.059–1.804)	1.475 (1.043–2.085)	1.321 (1.063–1.641)
Ischaemic heart disease	0.470 (0.189–1.169)	0.701 (0.328–1.497)	0.517 (0.240–1.112)	0.772 (0.446–1.339)
Stroke	0.674 (0.285–1.597)	0.906 (0.478–1.718)	0.694 (0.340–1.418)	0.877 (0.551–1.394)
DM	3.383 (1.715–6.673)	2.480 (1.489–4.129)	2.238 (1.379–3.632)	1.786 (1.263–2.527)
Psychiatric disorders	2.665 (1.495–4.750)	1.294 (0.916–1.827)	2.135 (1.425–3.198)	1.607 (1.229–2.101)
Any of diseases above	1.477 (1.117–1.952)	1.319 (1.088–1.599)	1.578 (1.267–1.966)	1.316 (1.134–1.528)
With a past history of CVD, DM, or psychiatric disorders				
CVD	0.416 (0.254–0.683)	0.334 (0.224–0.497)	0.539 (0.382–0.762)	0.526 (0.406–0.681)
Hypertensive disease	0.391 (0.222–0.688)	0.320 (0.207–0.494)	0.463 (0.304–0.706)	0.464 (0.344–0.626)
Ischaemic heart disease	0.165 (0.022–1.253)	0.463 (0.142–1.508)	0.408 (0.108–1.543)	0.438 (0.135–1.417)
Stroke	0.875 (0.293–2.610)	0.617 (0.240–1.584)	1.055 (0.449–2.475)	0.612 (0.268–1.397)
DM	0.186 (0.075–0.460)	0.297 (0.138–0.640)	0.265 (0.128–0.551)	0.424 (0.240–0.749)
Psychiatric disorders	1.651 (0.822–3.317)	1.221 (0.693–2.153)	0.828 (0.492–1.395)	1.089 (0.704–1.685)
Any of diseases above	0.385 (0.259–0.573)	0.407 (0.299–0.554)	0.611 (0.485–0.770)	0.667 (0.556–0.800)

CVD, cardiovascular disease; DM, diabetes mellitus.
[a]Hazard ratios refer to the risks among suicide completers' family members, when compared with non-bereaved family members.
[b]From the Cox proportional hazard model, after adjustment for age, area of residence, and socioeconomic status.
[c]From the stratified Cox proportional hazard model with the PWP total time model, after adjustment for age, area of residence, and socioeconomic status.

In the present study, we did not find a significant increase in the risk of hospitalization for ischaemic heart disease and stroke among suicide completers' family members, except for hypertensive disease in both groups with and without a past history. This might be related to insufficient statistical power due to a relatively small sample size and a short follow-up period. An additional follow-up study would be helpful in determining the impact of suicide loss on the cardiovascular system.

Diabetes mellitus

A previous non-specific bereavement study showed that parents who had lost a child had approximately twice as high a risk of hospitalization for type 2 DM.[16] The current study is consistent with that finding for subjects who did not have a past history of DM, although suicide loss may induce more severe psychological stress than typical bereavement.[17,25] Several studies have reported that psychological stress from suicide loss develops or worsens the symptoms of DM through an increase in the levels of fasting blood glucose and stress hormones such as cortisol.[26,27] Thus, it is plausible that suicide completers' family members who have had impaired glucose tolerance or undiagnosed DM might develop DM after a suicide loss, resulting in hospitalization. In the current study, the risk of recurrent hospitalizations for DM during the year after a suicide loss was lower than that for the first hospitalization. This might be because there were more individuals with more than two hospitalizations for DM in the comparison group. Because aggravation of DM is preventable by early detection and regular follow-up care, constant medical attention or supportive care might be necessary, especially among the elderly who have experienced a suicide loss.

Strengths and limitations

In previous studies on suicide loss, suicide completers' family members were recruited by advertisement or phone,[7,8] and 33 and 67%, respectively, of individuals agreed to participate. Selection bias may have been a factor in those studies because negative cultural attitudes towards mental illnesses[2,28] make it difficult to recruit a representative sample of suicide completers' family members in Asian countries. Thus, using medical care utilization data is a necessary method for accessing information about suicide completers' family members and their health status. To our knowledge, this study is the first to investigate the effect of suicide loss on the risk of hospitalization for CVD, DM, and psychiatric disorders using representative family members of both suicides and matched comparison individuals. Although we could not compare the effect of suicide loss with that of non-suicidal loss on CVD and DM risks, our study exposes the risk of cardiometabolic health in the management of individuals with suicide loss in family. However, there are several limitations to this study. Because of the family-based sampling method, the baseline characteristics of each family member might not have been controlled. In particular, there were differences in the distribution of area of residence between suicide completers' family members and the comparison group. However, the notable regional inequality in access to medical care was not observed in this study, which might be due to National Health Insurance in the Republic of

Korea.[29] Thus, the difference in the distribution of area of residence might not have distorted our results. Secondly, inaccuracy in the diagnosis code from the health insurance claims data might lead to misclassification bias. However, we considered hospital admission as an endpoint, which likely has high accuracy.[30–32] Owing to the National Health Insurance in the Republic of Korea, almost all hospital admissions for CVD, DM, and psychiatric disorder are covered, so collectively, misclassification bias might be non-differential. We also identified past history of CVD, DM, or psychiatric disorders, using health insurance claims data obtained 1 year before suicide loss, leading to an underestimation of the true prevalence of those illnesses. However, we applied the same period to the suicide loss group and the comparison group, which minimizes bias in our results. Thirdly, although a family-based sampling process was used in order to minimize the effect of relationship (i.e. spouse, offspring, and sibling) between suicide completers and family members, we could not identify those relationships due to limitations in the HIRA data. Thus, the relationship might act as an unmeasured confounder. However, the confounding effects of relationship might be less likely to distort our results because psychological distress over societal stigma of suicide might be amplified by family members' age.[33] In future studies, it is necessary to investigate the impact of suicide loss on family members by the relationships with suicide completers within a certain age group to develop targeting strategies.

In conclusion, the present results suggest the adverse effect of suicide loss on family members' cardiometabolic health and indicate a need to prevent CVD and DM after suicide loss.

Supplementary material

Supplementary material is available at *European Heart Journal* online.

Authors' contributions

C.K. and S.H.J. participated in the design of the study. C.K., S.H.J., and Y.J.C. contributed to the data collection. M.S., J.S., S.-K.C., and J.C. analysed the data. J.C., S.H.J., and C.K. wrote the manuscript. C.K., J.C., I.S., D.C.S., and K.M.R. were involved in the revision of the manuscript. C.K. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Conflict of interest: The researchers conducted this study independently from the funding sponsor. The sponsor had no involvement in the design and conduct of the study, in the collection, analysis, and interpretation of the data, or in the preparation, review, and approval of the manuscript.

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